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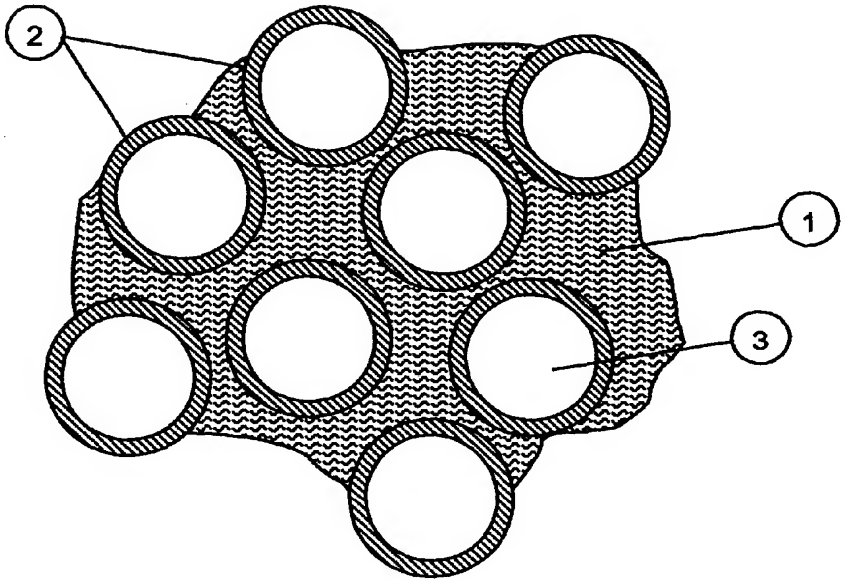
(54) Title: BIOGRADABLE HOLLOW FIBRE COMPOSITE IMPLANT



(57) Abstract: The present invention relates to the field of prosthetic devices used as tissue scaffold for providing mechanical strength and support for the growth of bone tissue in-vitro. More particularly the invention provides a biodegradable three-dimensional porous scaffold for the replacement or repair of injured or diseased bone without sacrificing the stiffness and strength required for fulfilling its mechanical function due to its porous structure. A bioabsorbable composite prosthesis formed by fibre reinforcement of a bioabsorbable polymer matrix by means of bioabsorbable hollow fibres to form a porous composite prosthetic device, wherein the bioabsorbable polymer matrix has a degradation rate greater or equal to the bioabsorbable hollow fibre.

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BIODEGRADABLE HOLLOW FIBRE COMPOSITE IMPLANT

The present invention relates to the field of prosthetic devices used as tissue scaffold for providing mechanical strength and support for the growth of bone tissue in-vivo and in-vitro.

More particularly the invention provides a biodegradable three-dimensional porous scaffold for the replacement or repair of injured or diseased bone without sacrificing the stiffness and strength required for fulfilling its mechanical function due to its porous structure.

For repair of damaged tissue to take place, the tissue must be supported in a fairly stable condition. In the case of structural tissue such as bone, it is naturally healed at the trauma site provided the site is not disrupted. Such support include casts and slings externally, or rods, pins and fracture plates internally in severe cases.

The present methods for treatment of degenerative joints and severe fractures include evasive reconstruction surgery by which man-made prosthetic devices are inserted at the location of the injury/degeneration. To date, most if not all such devices are manufactured from non-bioabsorbable materials such as non-bioabsorbable polymers or more commonly metals such as Chrome Cobalt or Titanium alloys (e.g. hip prosthesis and fracture plates). In the case of prosthetic joints, such devices remain as permanent implant in the patient for at least the period which it fulfils its function (i.e. fracture of the device due to fatigue or physiologically triggered failure such as bone resorption). In the case of fracture plate however, their use is far more transient, and the fracture fixation device is removed once the injury to the bone has been healed.

In both of the above uses, the device is removed form the patient using evasive surgery. It is however desirable if these foreign materials would be replaced by living tissue as the body repairs the injured area.

It has been shown that bioabsorbable implant with porous structure provides advantages to an implant in contact with bone or other tissue by allowing the tissue to grow into the pores and accelerating new tissue formation. Porous synthetic matrices forming bioabsorbable tissue scaffold for tissue regeneration both in vivo and in vitro are studied in the prior arts.

Bioabsorbable surgical devices such as pins, screws, plates, tacks, intramedullary nails are being used for hard and soft tissue fixation.

US5,338,722 (Bauer et. al) describes an implant material based on a composite material of calcium phosphate particles and bioabsorbable polymer, in which the proportion of calcium phosphate ceramic particles is at least 50% by weight. Bioabsorbable polymer bridges resulting in a three-dimensional open pore structure join the particles to one another.

More recently EP 992,251A1 (de Bruijn et. al.) describes a tissue scaffold material based on destructured natural starch-based polymer. The device may be made partial or fully porous, obtained as a result of ordered fibres (e.g. weaving) or open cell foams (e.g. as a result of salt addition or foaming agents).

One of the problems associated with porous tissue scaffolds such as US5338722 and EP 992251A1 is that, although the presence of porosity is an important requirement for the tissue generation and growth, it reduces the stiffness and strength of the component by replacing parts of the component with large number of voids. This reduction can be higher in the case of open porous structure formed by interconnecting pores. This reduction in strength is an important limiting factor for orthopaedic components, which have to

carry the skeletal loads at the site of injury as well as fulfilling their role as tissue scaffold for repair of the injury.

Another problem associated with porous tissue scaffolds is that of sterilisation. Devices incorporating biodegradable polymers cannot be subjected to autoclaving, and must be sterilised by gamma or E-beam radiation or by exposure to ethylene oxide (EtO) gas. Irradiation, particularly at the doses above 2 Mrd, can induce significant degradation of polymer chains, resulting in reduced molecular weight as well as influencing final mechanical properties and degradation time. Although sterilisation of planer mesh type structure can be achieved successfully, for a three-dimensional component with continuous pores (i.e. interconnecting pores) the problems associated with the use of current sterilisation techniques are as follows:

- Any secondary shaping processes such as machining the component to obtain a perfect geometrical match between the component and the host tissue may result in contamination of the pores buried deep in the body of the component due to their continuous structure.
- Difficulty of ensuring sterilisation of pores positioned deep in the component in particular following aforementioned secondary shaping processes such as machining.
- Difficulty in the removal of highly toxic EtO gas from the pores prior to packaging of the component.

The above problems are further exacerbated by the unstable nature of the bioabsorbable polymers requiring controlled humidity and temperature conditions during sterilisation process.

To overcome the above problems US 5,522,895 (Mikos) describes a biodegradable, bioabsorbable three-dimensional template for repair and replacement of diseased or injured bone that has the capacity of being

rendered porous either in vitro or in vivo. A biodegradable pore forming component is mixed within a continuous matrix formed of biodegradable material, the pore-forming component having a rate of degradation that exceeds that of the matrix. As a result, the problem associated with sterilisation process is reduced to surface sterilisation of the component. However, the rate at which the pore-forming compound is absorbed may not match the rate at which the new strengthening tissue is formed, resulting in a porous component with substantially reduced stiffness and strength. Therefore the problem due to the loss of stiffness and strength due to the presence of the pores remains.

To overcome the loss of stiffness due to the presence of pores in the implant, WO 00/13717 patent (Törmämlä et. al.), describes a bioactive, bioabsorbable surgical devices fabricated of bioabsorbable polymers, copolymers or polymer alloys that are self reinforced and contain ceramic particles or reinforcement fibres and porosity. Although the above proposal overcomes the loss of stiffness due to the presence of pores by inclusion of reinforcing particles and short fibres, the size, density and orientation of the voids in the final device cannot be controlled and can be associated with defect inducing manufacturing technique.

The proposed invention will overcome the above shortcomings by forming a porous bioabsorbable composite implant which provides the porous structure with desire density and orientation required for tissue generation without the loss of stiffness and sterilisation problems stated above.

According to one aspect of the present invention there is provided a bioabsorbable composite prosthesis formed by fibre reinforcement of a biodegradable polymer matrix by means of biodegradable hollow fibres so as to form a porous composite prosthetic device.

In one embodiment, the reinforcing biodegradable hollow fibres are substantially long so as to form a composite prosthetic device with continuous

porous structure. The fibres may be oriented in a given direction using three-dimensional weaving techniques depending on the tissue being replaced so as to optimise its stiffness and strength during its life and provide a stable condition for the growth of new tissue.

In yet another embodiment, the reinforcing biodegradable hollow fibres may be of discrete length so a to form a composite prosthetic device with discontinuous porous structure. The orientation of these discontinuous fibres may be controlled by manufacturing process in GB217042B (Bevis et. al.) so as to optimise the stiffness and strength of the composite prosthetic device. This manufacturing process controls the alignment of fibres, fillers and polymer molecular chains to enhance the mechanical properties of the moulded part in a given direction.

In a preferred embodiment, the hollow biodegradable reinforcing fibres may be coated by osteo-conductive material such as hydroxyapitite, a calcium phosphate having empirical formulae $Ca_5 (PO_4) OH$.

In yet another preferred embodiment, the hollow biodegradable reinforcing fibres may be filled with bioactive substances such as growth factor, a hormone or therapeutic agent to induce, promote or support tissue ingrowth and repair.

In an embodiment the hollow biodegradable reinforcing fibres may be porous across the wall of the fibre so as to enhance the flow of nutrients and biological wastes to and from the growth sites. An example of such fibre is presented in FR 2566003 (Aptel et. al).

Embodiments of this invention will now be described by way of example with reference to the accompanying drawings in which:

Figure1 is the schematic cross sectional view of the proposed porous composite containing hollow fibre

cartilage between the two bones is damaged. Current practices for treatment of such condition includes resurfacing of the joints using ceramic or metallic implants (see for example WO 00/45750, Pfaff et. al.). It is however advantageous to repair the damaged cartilage by means of tissue regeneration. Referring to Figure 5, the intermediate component (9) of the proposed prosthetic device is formed in the shape of the required bearing surfaces between the two bones (2) with the reinforcing hollow fibres arranged tangentially to the bearing surface. The intermediate component is fixed on one side by means of a stem (8) into the first bone (2) and forms a bearing surface with the second bone (2) on the second side.

In a preferred embodiment, the intermediate component may be seeded with the host tissue in the laboratory prior to implantation so as to allow faster recovery after implantation.

I claim:

1. A bioabsorbable composite prosthesis formed by fibre reinforcement of a bioabsorbable polymer matrix by means of bioabsorbable hollow fibres so as to form a porous composite prosthetic device.

2. A bioabsorbable composite prosthesis as claimed in claim 1 wherein the bioabsorbable polymer matrix has a degradation rate greater or equal to the bioabsorbable hollow fibre.

3. A bioabsorbable composite prosthesis as claimed in claim 1 wherein the reinforcing bioabsorbable hollow fibres are substantially long so as to form a composite prosthetic device with continuous porous structure.

4. A bioabsorbable composite prosthesis as claimed in any proceeding claim wherein the fibres are oriented in a given direction using three-dimensional weaving techniques to optimise its stiffness, strength and porosity in a given direction.

5. A bioabsorbable composite prosthesis as claimed in claim 1 wherein the reinforcing bioabsorbable hollow fibres are of discrete length forming a composite prosthetic device with discontinuous porous structure.

6. A bioabsorbable composite prosthesis as claimed in claim 5 wherein the orientation of discrete bioabsorbable fibres are controlled to optimise the stiffness, strength and porosity of the composite prosthetic device.

7. A bioabsorbable composite prosthesis as of any of above claims wherein the hollow biodegradable reinforcing fibres are coated by osteo-conductive material.

8. A bioabsorbable composite prosthesis as claimed in claim 6 wherein the osteo-conductive material is hydroxyapitite.

9. A bioabsorbable composite prosthesis as of any of above claims wherein the hollow biodegradable reinforcing fibres are filled with bioactive substances such as growth factor, a hormone or therapeutic agent to induce, promote or support tissue ingrowth and repair.

10. A bioabsorbable composite prosthesis as of any proceeding claims wherein the hollow biodegradable reinforcing fibre have porous walls.

11. A bioabsorbable composite prosthesis as of claim 1 or 2 in the form of device comprising a stem for implanting the device into a bone and an intermediate component forming a bearing surface at a joint between two bones.

12. A bioabsorbable composite prosthesis as claimed in claim 11 wherein the stem is threaded for fixation on to the bone.

13. A bioabsorbable composite prosthesis as claimed in claim 12 wherein the thread on one end of the stem is handed relative to the other.

14. A bioabsorbable composite prosthesis as claimed in claim 11 wherein the intermediate component is seeded with tissue cells.

15. A bioabsorbable composite prosthesis as claimed in claims 11 or 12 wherein the intermediate component is seeded with cartilage cells.

16. A composite implant prosthesis substantially as hereinbefore described with reference to the accompanying drawings.

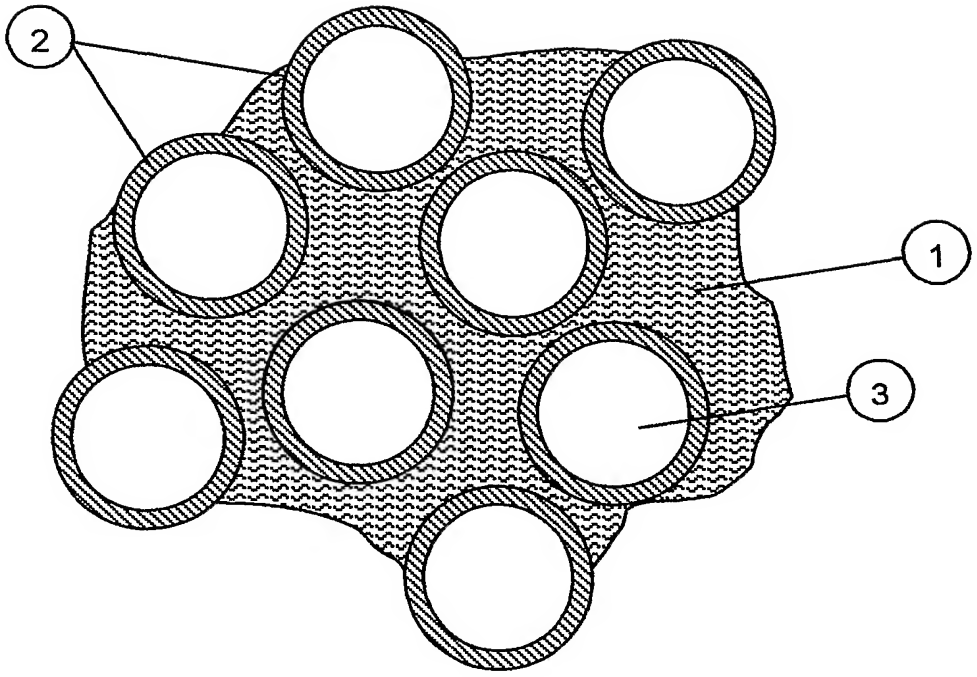

Figure 1